Preliminary Results of an Investigation Into the Impacts of Piscivorous Predation on Juvenile Chinook (*Oncorhynchus tshawytscha*) and other Salmonids in Salmon and Shilshole Bays, King Co. WA

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Introduction

As part of the Lake Washington studies it was proposed that predation may be a significant mortality of juvenile salmon. Since 1996 piscivorous predation has been studied cooperatively by USFW, UW, WDFW and the MIT Fisheries Department (Brocksmith, 1998; Fayram, 1997;Tabor, 1996,1997; Warner and Footen 1997,1999). Predation in freshwater has been investigated from the Cedar River to a few hundred meters above the Hiram Chittenden Locks. Preliminary results from these studies indicate that predation on sockeye (*Oncorhynchus nerka*) salmon by the primary predators in Lake Washington may be exceeding the upper limit of predation mortality expected during the juvenile sockeyes freshwater life history. Significant levels of predation were also observed on juvenile chinook (*Oncorhynchus tshawytscha*) by smallmouth bass (*Micropterus dolomieui*) in the lakes' Ship Canal.

The purpose of this study was to provide some insight into the level of predation by piscivores on juvenile chinook and other salmon occurring in the near-shore areas of the estuary west of the Hiram Chittenden Locks. Additional investigations were made into habitat types and lock operations, how they effect piscivorous consumption of chinook smolts, and how they effectthe nearshore distribution of juvenile chinook and piscivores.

Salmon and Shilshole bay are adjacent to the north end of the city of Seattle, King Co. WA (Figure 1). The study area is tidal, stretching from the Locks at the south-east end and Golden Gardens Park at the northern end with a mean tide of 8 feet and a range of 11.7 feet.

The study area was broken down into two locations. The inner bay and outer bay. Each location had seven sample sites. The criteria for separating inner and outer bays was exposure and criteria for choosing a sample site was governed strictly by beach availability (Mumford, 1991). More detailed description of each sample location will be in the final report.

Salmon Bay (inner bay) is a protected area between Puget Sound and the Locks. It receives freshwater discharge from the Lake Washington system via the Locks. The beaches have a shallow sloping gradients ranging from 6 to 12 %. The shoreline consists of private and commercial residences some of which overhang into the wetted area during high tide. Salmon Bay is dissected by a dredged shipping lane with a minimum depth of 30 feet. Nearly 90% of the shoreline is armored by bulkheads or rip rap. Shilshole Bay (outer bay) is an exposed area. Beaches sampled were limited to the shoreline to the west adjacent to the north end of Discovery Park, a beach along the breakwater on the east side of the bay that protects Shilshole Marina, and the beaches at

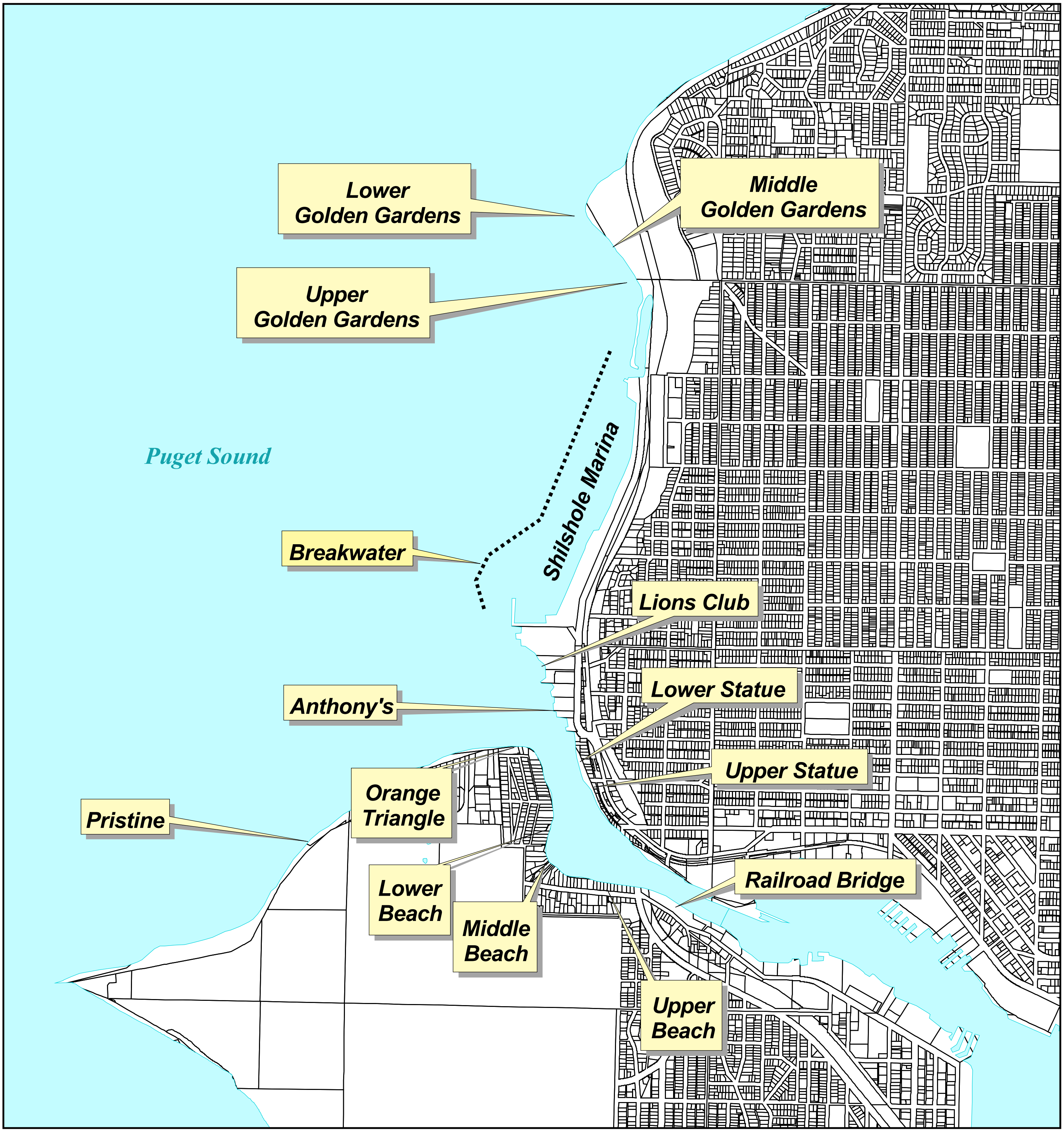

Figure 1: Sample Sites

Shilshole Bay

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KING COUNTY

500 0 500 1000 1500 2000 2500 Feet

N W E S

February 27, 2001

Legend

Water Features

Golden Gardens Park also located on the east side of the bay. A small tributary enters the study area at the southern end of Golden Gardens (City of Seattle, 1983).

Methods

Fish were caught using a beach seine net standard to past Lake WA nearshore sampling efforts (Martz, 1995). We sampled during the first high slack tide. Each study location was sampled twice a week, twice a month. Once caught fish were identified to species and either tallied or sampled for stomach contents based on suspected level of piscivory. Habitat data was also collected at each sample location. Wolman's (Wolman, 1954) pebble counts were used to provide a course resolution of intertidal substrate composition at each study site. Gradient, length, width, percent *Ulva* and *Fucus* cover and number of significant pieces of woody debris were also tabulated at each study site.

In the lab stomach sample contents was sorted and identified. Fish were identified to species when possible using diagnostic bone analysis. Other prey items were identified to family. Wet weights were taken for all prey items. Prey fish were measured when possible. All samples were then preserved and archived.

For the diet analysis percentages of prey items by wet weight were calculated. Population estimates were made using catch per unit effort and meters of shoreline data. These were used in simple consumption estimates calculations were the frequency of occurrence of the specified prey item in predator stomach samples was multiplied by the population estimate and the number of days that the specified prey were present in the intertidal areas of the estuary. Consumption calculations that incorporate temperature and metabolic activity will be calculated in the final report.

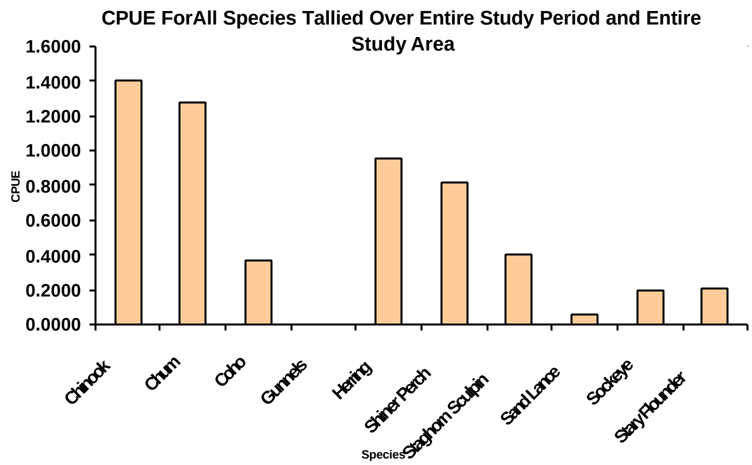
Results

<u>Catch</u>

Most of these results will focus on the inner bay. We sampled 4,176 m of shoreline from April to September 2000 in the inner and outer bay study areas. The sampling comprised of 99 sets in the Inner bay and 38 sets in the outer bay. Overall 23,816 fish were caught. One hundred and forty four of these were sampled for stomach contents. Non-piscivorous fish caught were tallied. Smolts were identified to species and hatchery and wild smolts tallied separately. Hatchery reared smolts were identified by the absence of the adipose fins which were removed at the hatchery.

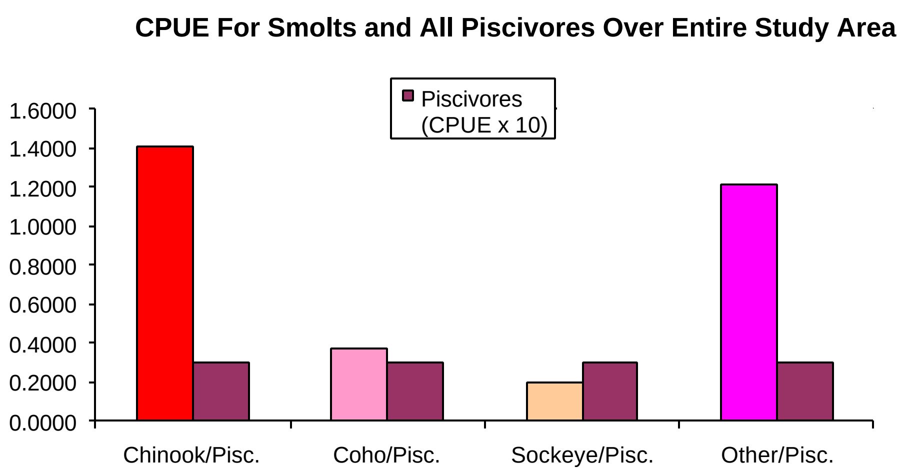
Catch per unit effort (CPUE) for all species tallied for the entire study area and period are as follows. This chart does not include fish sampled for stomach contents(Figure 2). The units in this analysis are fish per meter of shoreline.

Figure 2. Catch per unit effort for all species tallied.



A chart showing smolt catch per unit effort by species and total piscivore catch per unit effort for the entire study area and period is shown below (Figure 3).

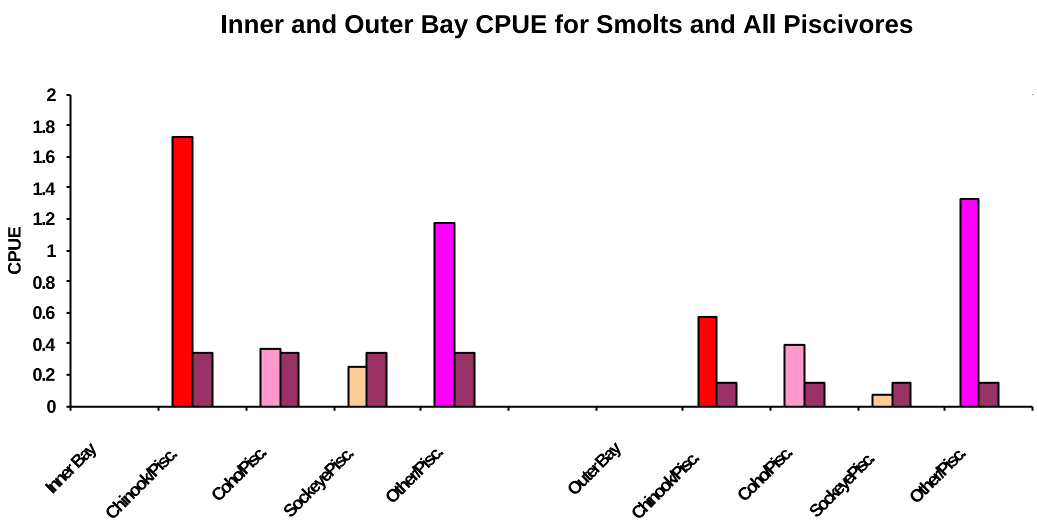
Figure 3. Catch per unit effort for all smolts and piscivores.



The high ratio of prey to predator can be seen in chinook and other smolts; these ratios are reflected in the diet data by the high frequency of occurrence.

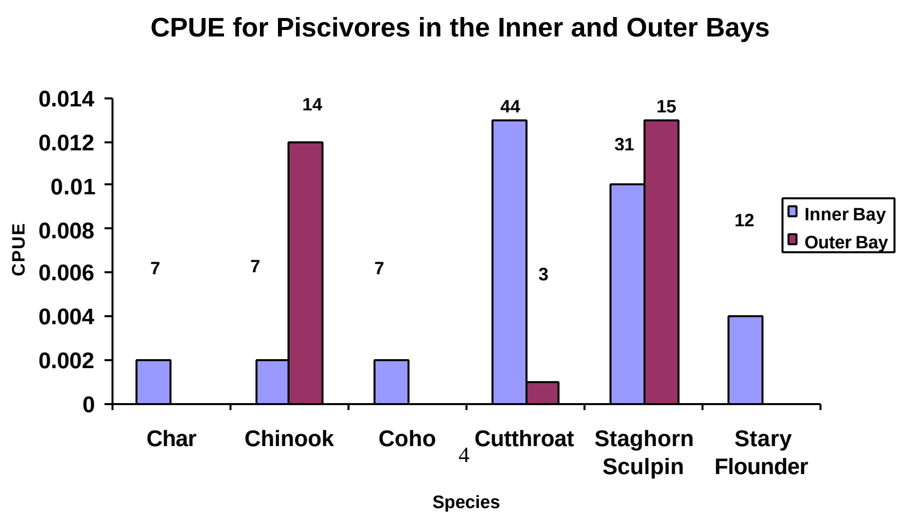
The following chart shows predator catch rates and distribution between inner and outer study locations (Figure 4).

Figure 4. Catch per unit effort for smolts and piscivores in the inner and outer bays.



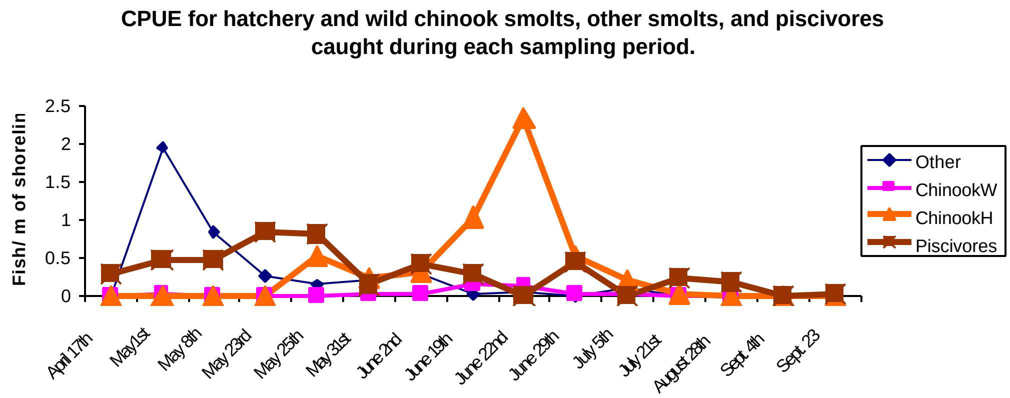
Sea-run cutthroat (*Oncorhynchus clarki*) were the most abundant predators in the inner bay followed by staghorn sculpin (*Leptocottus armatus*). The primary predators sampled in the outer study location were staghorn sculpin and resident chinook or blackmouth. Catch per unit effort for staghorn sculpin was higher in the outer bay than in the inner bay (Figure 5).

Figure 5. Catch per unit effort for piscivores sampled in the inner and outer bays.



The chart below shows CPUE for hatchery, wild chinook smolts and chum (*Oncorhynchus keta*) smolts in relation to piscivore CPUE (Figure 6).

Figure 6. CPUE for smolts and piscivores caught in the inner bay.



*Piscivores CPUE multiplied by 10.

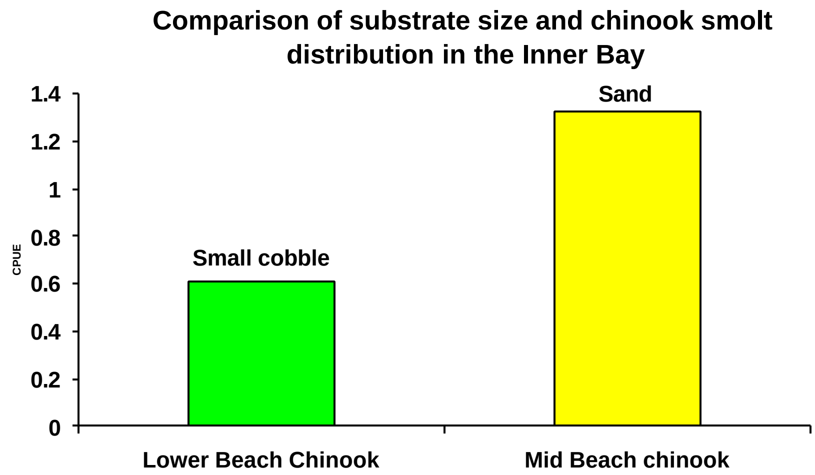
It does not appear that increases in chinook in the inner bay resulted in a predator response. The expected response would be an increase in piscivore CPUE. These data show a decrease in predator CPUE as chinook smolts catches increased. However, piscivore CPUE in the inner bay does indicate a lagged response to the high chum smolt densities during the early part of the sampling period.

Habitat

The following are some preliminary analyses of the habitat and fish distribution data for the inner bay. The colors are indicators of substrate size (the darker the color the larger the substrate) and percent *Ulva* and *Fucus* cover. A linear regression showed that as substrate size increased so did the percent of *Ulva* and *Fucus* (R^2=.83) Literature has indicated that areas with high *Ulva* and *Fucus* densities are important habitat for fish occupying the inter-tidal zone (Schreffler, 1995). We tested for habitat preference by chinook smolts and piscivores in hopes of gaining some insight into how habitat effects predator and prey distributions. Many factors can contribute to fish distribution. In order to minimize those effects only adjacent beaches with significantly different habitat types were tested. Therefore differences between Mid. Beach chinook smolt catches and piscivore catches were compared to Lower Beach catches to test for differences in sand and medium (less than or equal to 25mm) sized substrate. In addition fish catches at Upper Statue and Lower Statue large (greater than or equal to 50mm) and medium sized substrate respectively were made. The final report will include a more detailed analysis including outer bay data and hatchery and wild habitat preferences.

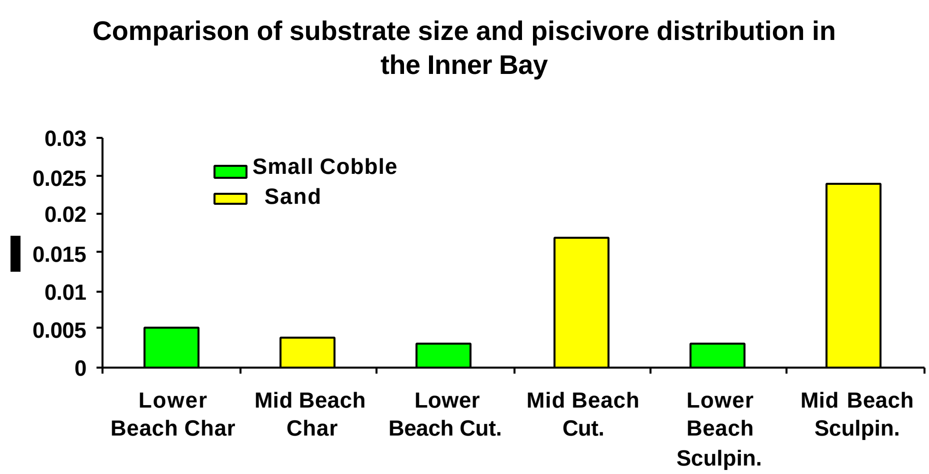
A goodness of fit test to see if chinook smolts had a habitat preference between sand and cobble dominated habitat less than or equal to 25mm showed that significantly more chinook were caught in the sandy habitat (Figure 7).

Figure 7. Distribution and of smolts by habitat type.



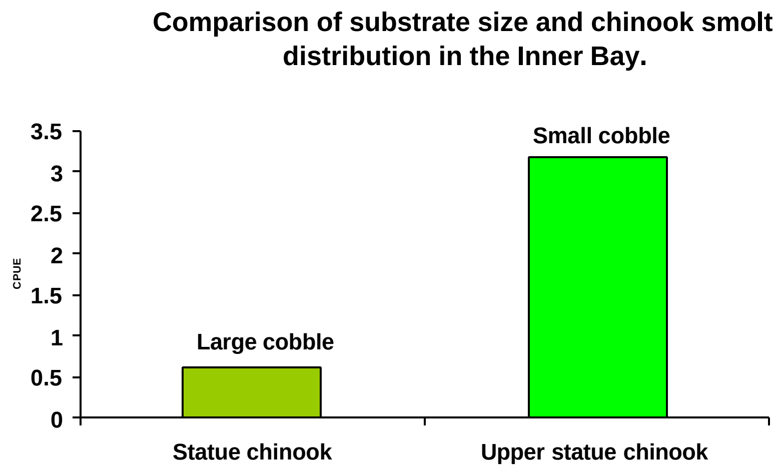
The same comparison was made for piscivores caught at the sand and small cobble study sites. These data showed cutthroat and sculpin were more prevalent in the sand, and char had no preference (Figure 8).

Figure 8. Distribution of piscivores by habitat type.



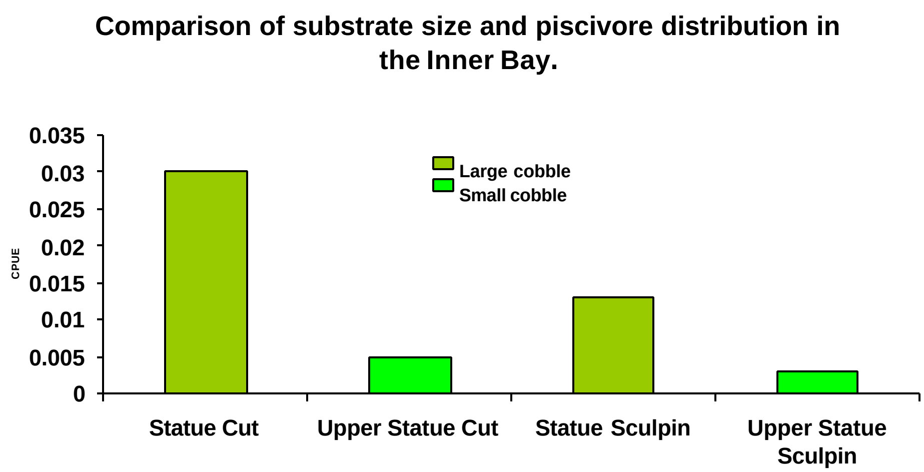
Similar comparisons were made between the Lower Statue site a large cobble beach with a mean substrate size of 45mm and the Upper Statue site with a mean substrate size of 25mm. These data showed that chinook smolts preferred the smaller substrate (Figure 9).

Figure 9. Distribution of Chinook smolts at large and small cobble study sites.



The opposite was true for the distribution of piscivores caught at the large and small cobble beaches. Significantly more cutthroat were caught at the large cobble beach than the small. Sculpin showed no preference (Figure 10).

Figure 10. Distribution of piscivores at large and small cobble study sites.

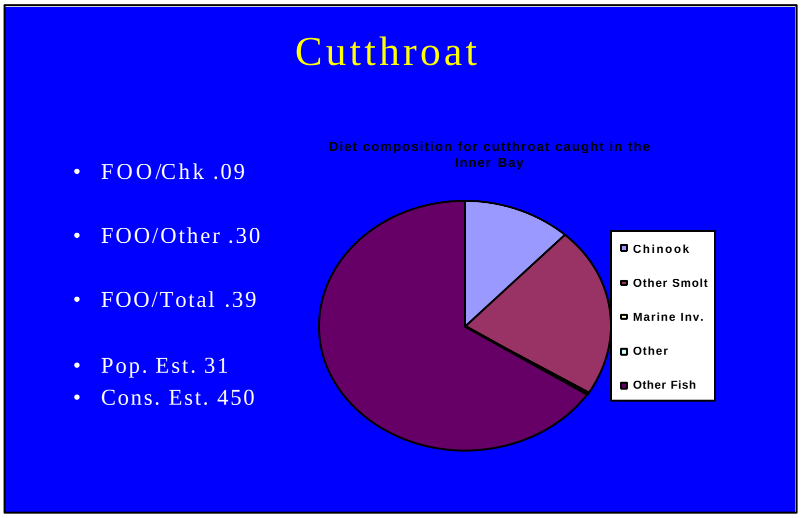


Diet

One-hundred and three piscivores were sampled in the inner bay including one adult sockeye and three two year old chinook, starry flounder, and one adult coho. Thirty-one juvenile salmon were consumed by cutthroat, char and sculpin, the only piscivores containing salmonids. Here is the breakdown by species for salmonid consumers.

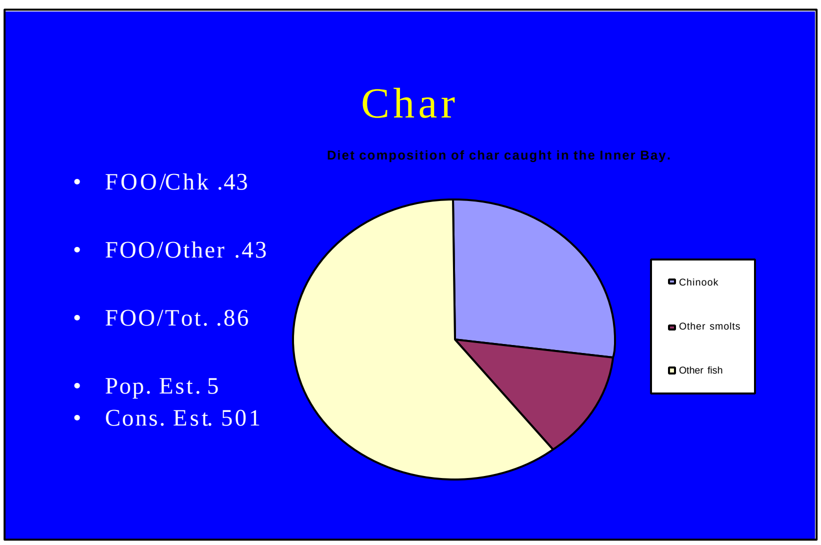
Chinook made up 12 percent of the cutthroat diet during the course of the study. Thirty-four percent were other smolts, mostly chum. The remaining 66 percent was other fish, primarily sand lance. Frequency of occurrence (FOO) was relatively high but because CPUE was so low the estimate of chinook consumption is low (Figure 11).

Figure 11. Cutthroat diet composition.



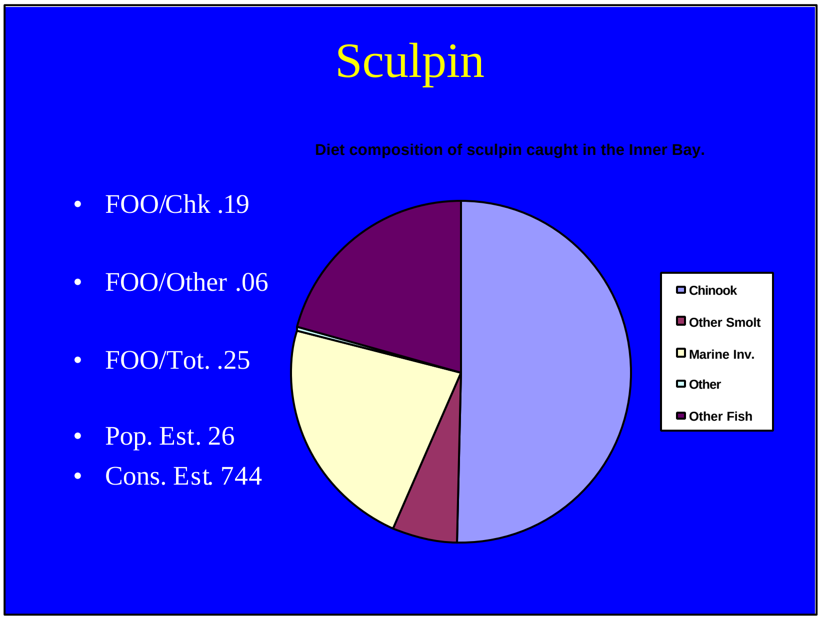
The char diet consisted of 27 percent chinook, 12 percent other salmonids and 60 percent other fish. Again the FOO is high but the population estimate is low so consumption will be low (Figure 12).

Figure 12. Char diet composition.



Fifty percent of the staghorn sculpin diet was chinook. This however is biased by one very fresh sample. Frequency of occurrence data helps to reduce the bias contained in wet weight percentages and in this case is high but again estimates of chinook consumption is offset by the low population estimate (Figure 13).

Figure 13. Staghorn sculpin diet composition.



Discussion

Catch

Although the freshwater lens extends only a few hundred meters (Houck, *per. com.* 2000) beyond the locks our CPUE for smolts in the inter-tidal zone dropped dramatically as the smolt slide use decreased. The importance of additional freshwater inputs the smolt slides create for migrating salmonids late in the migration period will be investigated further in the final report.

Our catches were fairly diverse including sensitive species such as gunnels, shiner perch, starry flounder, surf smelt and pacific herring. These species have been shown to be sensitive to anthropogenic influences so there presence can be indicative of a relatively healthy system (Wingert, 1979).

Bulltrout, a listed species, may be present in the inner bay. We caught seven char in this study location. Fin clips from each fish are being tested for species confirmation. Again the potential presence of a species sensitive to development is positive when considering the overall health of the estuary.

Habitat

It appeared that chinook smolt habitat use was density dependant. When chinook smolt densities were high they were found in large numbers showing a preference for sandy substrate. However although still preliminary, catches of chinook smolts that occurred at the beginning and end of the study when densities were lower appear to show a preference for cobble. More work need be done testing for a habitat preference by the piscivores and smolts earlier and later in the migration period.

Diet

Chinook consumption is happening, and as we would expect by the high prey to predator ratio it is happening quite frequently. This can be seen in the high FOO's seen in the three primary salmonid consumers in the inner bay. However this predation probably is not a significant problem because predator populations appear to be relatively low. Predator to prey size may also be playing a role in piscivore consumption of chinook smolts. Large prey may be affecting the distribution of smaller piscivores in the near-shore thus the sharp decline of piscivores in the near-shore during high prey densities. This relationship between prey and predator size and predator presence will be investigated further in the final report.

Future Research

Future research into the ecology of Salmon and Shilshole bays will help continue to develop our understanding of smolt behavior in the estuary. Increased sampling efforts when densities are lower will refine the picture of how chinook smolts (both hatchery and wild) are using the available habitat for rearing before and after the peak migration period. If indeed chinook show a preference for cobble substrate with high densities of *Ulva* and *Fucus* during this period then the impacts of cliff armoring and bulkheads as they relate to cobble recruitment on beaches should be addressed under ESA. In addition shoreline complexity from woody debris is low. Further investigation into the benefits of wood on beaches and the increased productivity it might provide is needed. Currently most floating wood in Shilshole bay does not reach the beaches but is retrieved by the Army Corps of Engineers and taken away on barges. Should this wood be made available for habitat enhancement of the intertidal zone?

Increasing the overall sampling effort will also help refine our knowledge about chinook behavior in the estuary. How does the reduction and direction of freshwater inputs from the locks impact the pathways that smolts take from the freshwater lens directly below the Locks to the near-shore habitat in the inner bay? How are the smolts using the water directly in front of the Locks, in Shilshole Marina and in deeper water in the shipping lane of the inner bay? We should attempt to apply additional sampling techniques in these areas 2001.